Acta Biologica Szeged *18* (1—4), pp. 167—180 (1972)

MOLLUSCA PERIODS IN THE SEDIMENTS OF THE HUNGARIAN PLEISTOCENE VII. THE LOWER HUMID PERIOD OF THE BORING OF FELSŐSZENTIVÁN

† A. HORVÁTH

Department of Zoology, Attila József University, Szeged

(Received June 30, 1971)

This paper is the seventh part of a series begun in 1962. The series deals with the Mollusca periods of a 77 m deep boring at Felsőszentiván. On the basis of the *Mollusca* fauna, the boring has been divided into the following five periods:

I. upper arid period, 1,6—11 m; II. upper humid period, 11—14,5 m; III. middle arid period, 14,5—44,2 m; IV. lower humid period, 44,2—56,5 m; V. lower arid period, 56,5—77 m. The aim of this work is the treatment of the lower humid period (IV). The method of the previous papers is followed. On the basis of the *Mollusca* fauna, the period is broken down into subperiods. These are evaluated ecologically. Finally, an attempt is made to establish the time of formation of the deposits by means of the geological chronology and the Milankovich—Bacsák astronomical climate-curve.

Based on its appreciable aquatic fauna, the IV. or lower humid period can easily be distinguished from the neighbouring arid deposits above and below it. The further analysis of its fauna was used to break it down into eight subperiods, which are discussed below.

Subperiod IV/1, 44,2—45,4 m

The deposit is 120 cm thick, and consists of three 40 cm boring samples. The material of the uppermost sample is running sand, that of the other two fine sand with loess, into which are mixed mud and a little humus. The high values of the *Mollusca* exemplars altogather are well distinguished both upwards and downwards. Its upper limit is at the same time the boundary between the middle arid (III) and the lower humid (IV) periods too. Compared with the neighbouring sample of the arid period, the number of aquatic species is increased from 2 to 6, and the total number of individuals from 2 to 16. 26 species were found in the subperiod, and in these there are 887 individuals.

The aquatic fauna is represented by 10 species and 426 individuals. The species present in highest numbers of individuals are *Pisidium cinereum* (235), and *Bithynia leachi* (135). *Stagnicola palustris* (23) already has much fewer. The numbers of individuals of the other 7 species are low: *Gyraulus laevis* (9), *Gyraulus crista* (9), *Pisidium obtusale* (5), *Planorbis corneus* (4), *Anisus planorbis* (3), *Galba truncatula* (2), and *Valvata pulchella* (1). The high number of the slightly oligothermal *Bithynia leachi*, the absence of *Bithynia*

tentaculata which is at present much more frequent on the Great Hungarian Plain, the presence of *Gyraulus laevis* and *Valvata pulchella* which appear at present to have become practically extinct on the Great Plain, and the low number of *Planorbis corneus* which is common in our waters today but which was much rarer in the Pleistocene, are features reminiscent of a Pleistocene snail ecosystem and may mean a climate cooler than the present one. The *Mollusca* permit conclusions on the collective aquatic flora.

The amphibiotic snails are represented by 2 species and 155 individuals. The appreciable number of *Succinea oblonga* (151) corresponds to a favourably humid and suitably warm waterside environment. The *Succinea putris* (4) may mean a shady waterside environment.

The hygrophil ubiquists remain well behind the previous category as regards quantity, with 9 species and 276 individuals. If a parallel is drawn between them and the ubiquists of subperiod III/13, the adjacent subperiod upwards, the following results are obtained. The number of species here is one less, but only a single individual from the missing species *(Vallonia enniensis)* was present in subperiod III/13. The other 9 species are common. Here too, *Trichia hispida* (153) and *Cochlicopa lubrica* (41) are in first and second places, but here the numbers of individuals are much larger, clearly as a result of the higher moisture content. The numbers of individuals of the hygrophil *Deroceras agreste* (29) and *Vallonia pulchella* (19) too are substantially higher. *Pupilla muscorum* (15), which requires rather less moisture, is also present in higher numbers, but here it is not in the third place, but only the fifth. The amount of *Euconulus trochiformis* (8) is only a little higher. *Punctum pygmaeum* (6), *Vertigo pygmaea* (4) and *Vallonia costata* (1) occurred in the fauna of both subperiods in very small amounts. On the basis of the occurrence of the ubiquists, the environment of subperiod IV/1 was more humid, more mild, and had a richer flora than subperiod III/13.

Grove-dwellers: 4 species, and 33 individuals. The species are the same as those of subperiod III/13. There are slight increases in the numbers of *Perpolita hammonis* (16), *Arianta arbustorum* (13) and *Clausilia dubia* (3). This is the result here of an environment which had a milder temperature, was more humid, and was richer in flora. The *Columella edentula* subsp. *columella* (1) would mean cold and open vegetation, but its amount is insignificant.

The thermophilics are represented by only a single *Imparietule tridens,* from the upper sample. The cool and humid environment of the subperiod did not favour this category. The thermophilics merely vegetated in subperiod III/13 too, but nevertheless the living conditions there were more favourable, in the continental climate with more sunshine.

In the end, standing water developed during the subperiod; the maintenance and increase of this can be attributed to an oceanic climate. Grove vegetation grew on the banks of the water, and the temperature was somewhat cooler than that of today. The natural conditions underwent a change during the formation of the three boring samples. Compared with the uppermost sample of subperiod IV/2, deposited in the preceding period, the number of aquatic species in the lower sample increases from 2 to 8, and the total number of individuals from 17 to 132. The increase of the amphibiotic and ubiquist categories is significant, but much more moderate, while the grove-dwellers and thermophilics did not appear at all. The becoming milder of the climate

and the increase of the precipitation compared with the upper sample of subperiod IV/2 are striking, but this is the sample of subperiod IV/1 which exhibits the coolest and the lowest precipitation conditions. The much richer fauna of the middle sample indicates a considerable enhancement of the moderation of the climate and the precipitation. The aquatic fauna in the upper sample is strongly reduced as regards the number of individuals, and it has lost its leading role to come into third place behind the ubiquist and amphibiotic categories. As a result of the further significant increase of Succinea oblonga which preferably favours moderate warmth, and the simultaneous occurrence of the thermophilic *Imparietula tridens,* it can be concluded that this was a warmer period, and thus the reduction of the water can be attributed to the effect of a dry, warm climate.

Subperiod IV/2, 45,4—47,6 m

Its thickness is 220 cm, consisting of two 40 cm, ane 50 cm, and three 30 cm boring samples; the material is fine sand with loess and mud, and a little humus. Only 11 species and 236 individuals were found in it.

Its aquatic fauna consists of 4 species and 100 individuals. *Bithynia leachi* (90) predominates, and occurs in every sample, but the number of its individuals is much less than in subperiod IV/1. The other species appeared only sporadically and in small amounts. *Pisidium cinereum* (6) was found in only two samples, and *Galba truncatula* (3) and *Gyraulus crista* (1) in only one. Water was continually present, but nevertheless the numbers of aquatic species and individuals was very low compared with subperiod IV/1; this may be attributable to the lower temperature of the water.

Amphibiotic fauna: 2 species. *Succinea oblonga* (54) forms a complete series, but the number of individuals is generally much less than in subperiod IV/1. Since the humid environment necessary for the existence of the species as present, the decrease of the number of individuals may be explained by the cold. *Succinea putris* appears as only a single individual.

Hygrophil ubiquists: 4 species, 80 individuals. Compared with subperiod IV/1, the numbers of both species and individuals are strikingly low. *Trichia hispida* (43) dominates, but it occurs in only three samples, and in appreciable amounts only in the two lower ones. *Deroceras agreste* (31) forms a series, and is missing from only the lowermost sample. *Pupilla muscorum* (4) was found in only the two lowest samples, and *Cochlicopa lubrica* (2) in only the lowermost and the uppermost samples. These species endure the cold well, and sufficient moisture could be obtained on the waterside. Their poor numbers can be attributed to the chilling action of the moisture, and to the protective flora.

The inhabitants of the groves are represented by only one individual *Perpolita hammonis,* found in the uppermost sample. Their disappearance is due to the effect of the cold moisture and the mediocrity of the vegetation.

There were no thermophilic species; the cold, moist environment did not favour this category.

At the time of the formation of the deposits of this subperiod there was a cold, moist environment, standing water of a permanent nature but with a low temperature, and open vegetation. The poor vegetation led to the

conclusion of insufficient precipitation, and hence a continental climate, and in accordance with what was said above this was a cold continental cilmate. The water may have arisen from the thawing of the frozen soil. The relatively most favourable conditions for the fauna prevailed at the time of formation of the 46,9—47,2 m sample layer, and more than half of the individuals of the subperiod were found here. However, essentially different conditions can not be reconstructed from the fauna of this cample.

Subperiod IV/3, 47,6 — 49 m

140 cm thick, and comprising 5 boring samples: one of 40 cm, three of 30 cm, and one of 10 cm. Its material is mud with humus, with running sand. The high values of the *Mollusca* exemplara altogether are well defined both upwards and downwards. The number of species is 21, and that of the individuals 1153.

Aquatic fauna: 7 species, 167 individuals. The number of individuals decreases rapidly in the downwards direction: in the second lowest sample there were only 2 species and 3 individuals, and the lowermost sample did not contain any aquatic species. *Pisidium cinereum* (134) predominates, but its number of individuals is appreciable in only the two uppermost samples. *Bithynia leachi* (13) forms a series with a low number of individuals. The numbers of the other 5 species are slight: *Gyraulus crista* (10) occurred in only the three uppermost samples, *Stagnicola palustris* (6) in only the two uppermost, *Gyraulus laevis* (2) and *Anisus planorbis* (1) in only the uppermost, and *Pisidium obtusale* (1) in only the second sample. This subperiod was somewhat more humid than subperiod IV/2.

The amphibiotic fauna are represented by only *Succinea oblonga* (74). This forms a series. Its amounts in the three uppermost samples are small, and in the two lowermost samples appreciable; this can be attributed to the cold and to the milder temperature, respectively. Its high number of individuals in the two lowermost samples confirms the ample moisture, even with the total, or almost total, absence of aquatic fauna.

Hygrophil ubiquists: 9 species, 806 individuals. *Pupilla muscorum* (321) and *Trichia hispida* (303) predominate; their high numerical multiplication may have been caused by a milder and more humid environment compared with that of subperiod IV/2. *Vallonia costata* (58) was absent from subperiod IV/2, whereas it occurred here in a complete series. Together with the greater humidity it meant much more warmth. The situation of *Deroceras agreste* (28) did not change essentially. The following 4 species were likewise not found in subperiod IV/2. *Vallonia pulchella* (24) and *Euconulus trochiformis* (21) did not occur in the three uppermost samples, and this means a more humid and milder environment htere than in subperiod IV/2. *Vertigo pygmaea* (4) appeared in only the two lower samples, and *Punctum pygmaeum* (1) in only the lowest sample, with low numbers of individuals.

Overall, the number of species within the category here is 5 more than in subperiod IV/2; 5 species are found in perfect series, whereas there was no complete series in subperiod IV/2. The numbers of individuals here are much higher. The category is much more similar to that of subperiod IV/1, because the species themselves agree completely, although the quantitative distribution

there is different. On the basis of the category, the climate of subperiod IV/3 overall milder than that of subperiod IV/2, has more precipitation, is richer in flora, and has an oceanic nature.

Wood-dwellers: 2 species, 30 individuals. *Perpolita hammonis* (23) forms a complete series. With its low numbers of individuals this is striking, because the species does not appear in either the five higher or the five lower samples. It shows a higher humidity and a richer vegetation than in subperiod IV/2. *Pupilla sterri* (7) occurred in only the middle sample of the subperiod. It is at present a rock-dwelling species of the Alps and Carpathians; it does not live on the Great Hungarian Plain, and its occurrence points to a climate colder than that of today.

Thermophilics: 2 species, 40 individuals. *Imparietula tridens* (38) is totally absent from the two uppermost samples, occurs in the third with a single individual, and in the two lowermost samples with a high number of individuals, signifying appreciable warmth there. *Helicella hungarica* (2), which requires more heat and a drier environment, appears in only the two lowermost samples.

Overall, therefore, with the exception of the lowest sample, upwards increasing standing water existed in subperiod IV/3. Its climate was milder, and with more precipitation than in subperiod IV/2, and was of an oceanic type, while its vegetation was richer, and of a grove nature; however, it did not form a closed wood. The natural conditions during the formation of the deposit were not completely uniform. In the range 47,6—48,6 m the environment was cooler, moister, and richer in flora, because the aquatic fauna is almost totally confined to this period, while the bulk of the ubiquist fauna and the majority of the wood-dwellers were found here; on the other hand the number of *Succinea oblonga* individuals is low, and the thermophilics are represented by only a single individual. In the range 48,6—49 m the environment was warmer, drier, and poorer in flora, because the amounts of thermophilics and *Succinea oblonga* are high.

Subperiod IV/4, 49—51,9 m

This deposit is 290 cm thick, and consists of three 20 cm, three 40 cm, two 30 cm and one 50 cm boring samples. The material is mud with humus, with running sand (49—49,4 m), running sand with mud (49,4—50 m), and running sand (50—51,9 m). It is sharply defined both upwards and downwards by the low values of the *Mollusca* exemplars altogether. The number of species is 19, and of individuals is 519.

Aquatic fauna: 7 species, 115 individuals. There is no aquatic species in the two uppermost samples, and then on proceeding downwards a gradual increase of the aquatic fauna can be observed, although in contrast a decrease is found in two samples. *Pisidium cinereum* (51) has the most individuals, but of these 46 are from the lowest sample, and above this its amounts are insignificant. *Anisus planorbis* (38) forms a series in the six lowest samples, and is the most widerspread species of the subperiod. *Anisus spirorbis* (13) occurs in only the lowermost sample, and *Stagnicola palustris* (9) in only the three lowest samples. The roles of *Bithynia leachi* (2), *Valvata cristata* (1) and *Aplexa hypnorum* (1) are insignificant. The great majority of the individuals

(80) are to be found in the lowest sample, but even this sample is very sharply distinguished from the very rich aquatic fauna of subperiod IV/5. It can be concluded from the fauna that the standing water gradually dried up, and hence the climate was dry.

The amphibiotic category is represented by *Succinea oblonga* (134). In the two uppermost samples, from which the aquatic fauna are absent, there are only 8 individuals, in accordance with the drier conditions; lower down, however, its number of individuals by and large increases in parallel with the aquatic fauna, indicating increasing moisture. Practically one third of the individuals were in the lowest sample.

Hygrophil ubiquists: 8 species, 201 individuals. All 8 species were also to be found in subperiod IV/3, where the only additional species was *Punctum pygmaeum*, appearing as only a single individual. The total number of individuals in the category, however, is less than one quarter of the corresponding number for subperiod IV/3, although the deposit of subperiod IV/3 is less than half as thick as that of subperiod IV/4. This extensive decrease in the number of individuals may be attributed to the dryness. As the species most readily enduring the heat and dryness, *Pupilla muscorum* (55) preserved its leading role in spite of a large numerical reduction. The amount of *Cochlicopa lubrica* (52), which has higher moisture requirements, decreased considerably, although here it occupied not the third, but the second place. *Trichia hispida* (42) fell from second to third place. The characteristic reduction of the loess-snails was caused not only by the dryness, but also by the heat, since even in the lowest and wettest sample there were only 2 of its individuals. *Vallonia costata* (19) quite favours the heat and occurs in the drier places too, though with a strongly decreased number of individuals, but it remains in fourth place, as in subperiod IV/3. *Vertigo pygmaea* (15) is the only ubiquist which shows an appreciable increase compared with subperiod IV/3; it forms a series with low numbers of individuals, and is missing from only three samples. This can be attributed to the ability of the species to favour heat somewhat and to tolerate dryness. As a result of the dryness the hardy ubiquist *Deroceras agreste* (14) fell from fifth to sixth place with a considerable decrease. *Euconulus trochiformis* (3), which tolerates heat well but requires a fair amount of moisture, is confined to only the three lowest samples. The very large decrease of *Vallonia pulchella* (1) is brought about by the dryness. According to the above as regards the number of individuals of the ubiquist fauna this subperiod is much poorer than subperiod IV/3; the reason for this may be the dryness and the more open vegetation, and the direct exposure to sunlight.

The inhabitants of the groves are represented by only 4 *Perpolita hammonis* individuals. These occur in only two samples (50,3—51,2 m). From the point of view of the number of individuals these two samples are in second and third places, and in one of them the ubiquists too culminate. This may have been the part of the subperiod richest in flora, but of course there is no need here to conceive of woods.

Thermophilics: 2 species, 62 individuals. *Imparietula tridens* (60) forms a complete series, and culminates in the same sample as do the ubiquists. *Helicella hungarica* (2), which requires greater warmth and more open vegetation, was found in only two samples. The series of thermophilics thread-

ing their way through every sample of the subperiod is now met for the first time in period IV. This category indicates dry heat and open vegetation.

Overall, a dry, hot continental climate and open vegetation must be reconstructed for this subperiod. Standing water existed on the area, having been inherited from the subperiod below it (IV/5), and this gradually dried up. The fauna too was hard hit by the dissappearance of the water, and is the poorest in the three uppermost samples.

Subperiod IV/5, 51,9—52,7 m

The deposit is 80 cm thick, and consists of two 30 cm and one 20 cm boring samples. Its material is running sand. The *Mollusca* exemplars altogether are sharply defined both upwards and downwards by their high values. The number of species is 26, and of individuals 12 089.

Aquatic fauna: this comprises the bulk of the fauna with 14 species and 11 781 individuals. The hardy ubiquist *Pisidium cinereum* (3955) and the eurythermal, but somewhat thermophilic *Pisidium obtusale* (1730) are the dominant species. As regards their unusually high numbers it must be noted that both *Pisidium* species contain shelled young, and these have been included in the number of individuals. At all events, the two species lived under optimum conditions. *Anisus planorbis* (1569) and *Anisus spirorbis* (1386) are eurythermal species, but rather prefer the heat. *Gyraulus crista* (1192) is a eurythermal species, and is frequent in standing waters rich in aquatic flora. The basic form occurred as 334 individuals, and the var. *nautileus* as 858 individuals. The var. *nautileus* is at present also more frequent is Hungary. *Valvata pulchella* (1066) is oligothermal on the Great Hungarian Plain, and indicates colder conditions than those of today, but it must not be concluded that it was a considerably cold time, for the species is now frequent in Germany. *Pisidium personatum* (346) is oligothermal, but it also lives on the Great Hungarian Plain today. *Stagnicola palustris* (211), which favours marshy standing waters, and the slightly oligothermal *Galba truncatula* (200) are fairly frequent. The number of the moderately thermophilic *Segmentina nitida* (70) is also appreciable. The amounts of the preferably oligothermal *Anisus leucostoma* (28) and *Aplexa hypnorum* (16), and also of the *Anisus carinatus* (10) of West European origin, are all slight, but they do appear in every sample. The oligothermal *Bithynia leachi* (2) occurs in only the uppermost sample. The unusual richness of the aquatic fauna compared with the other subperiods can be attributed to the abundance of water, and this in turn to an oceanic climate with much precipitation. Essentially at the time of this subperiod there was standing water with a good supply of oxygen, overgrown with aquatic flora, and an oceanic climate somewhat cooler than today's, but still basically mild.

Amphibiotic fauna: 2 species, 258 individuals. *Succinea oblonga* (256) is everywhere much more than in subperiod IV/4, and this corresponds to the moist environment and the mild climate. *Succinea pfeifferi* (2) was found in only the lowest sample.

Hygrophil ubiquists: in all 7 species and 43 individuals. The sparsity of the fauna may be a consequence of the abundance of water, in so far as the area was presumably flooded several times by the water, and the development of the dry-land fauna was hindered. The dominant species are

Cochlicopa lubrica (18) and *Euconulus trochiformis* (7), and the roles of these two moisture-requiring species are increased compared to subperiod IV/4, while that of the species *Pupilla muscorum* (6) may have decreased as a result of the unfavourable moisture. The moisture-requiring *Vallonia pulchella* (5) appears in only the lowest sample, but only one individual was found in subperiod IV/4. *Vallonia enniensis* (3) was missing from the preceding four subperiods. It occurs here in all three samples and indicates some degree of warmth. *Deroceras agreste* (3) was slightly decreased compared with subperiod IV/4. *Vertigo pygmaea* (1) occurred in only the lowest sample, its great decrease having been caused by the high moisture. *Trichia hispida* is absent, although it formed a series in subperiod IV/4. The reason for the absence of the characteristic loess-snail may be the abundant moisture and the heat. In accordance with the above, the greater heat and moisture compared with subperiod IV/4 is also indicated by the ubiquists.

Grove-dwellers: 2 species, 7 individuals. *Perpolita hammonis* (6) appears in every sample, but the numbers of its individuals are small. At all events it points to moisture and a cool microclimate. Thus, in itself and in such small amounts it rather raises the idea of open vegetation. *Pupilla sterri* (1) in the lowest sample indicates a climate colder than the present one, because it is today an Alps-Carpathanians species. Its presence speaks against dense vegetation.

There are no thermophilics, although they formed a complete series in subperiod IV/4. The moisture was more than they could tolerate.

Overall, standing water of a permanent nature existed during the subperiod, and this was rich in aquatic flora and had a good oxygen supply. An oceanic-type climate prevailed; this was somewhat cooler than today's but was still basically warm. On the basis of the fauna the vegetation was locally of an open nature, but on the basis of the reconstructed climate the existence of deciduous groves and woods may be presumed on the Great Hungarian Plain.

Subperiod IV/6, 52,7—53,9 m

The deposit is 120 cm thick, and is composed of four 30 cm boring samples. The material is running sand, which is also mixed with mud in the two lowermost samples. It contains 29 species and 2790 individuals.

Aquatic fauna: 16 species, 1149 individuals. Pisidium cinereum (406), although with a strongly decreased number of individuals, continues to predominate. *Anisus spirorbis* (319), *Anisus planorbis* (178) and *Gyraulus crista* (69) form complete series here too, but compared with subperiod IV/5 their numbers of individuals are greatly decreased. With the *Gyraulus crista* species, the parent form is in a large numerical majority in the uppermost sample, and the var. *nautileus* in the third sample. The situation of the oligothermal *Anisus leucostoma* (35) is essentially the same as it was in subperiod IV/5. *Valvata pulchella* (28) remained in sixth place, but there was a very large decrease in the number of its individuals. The reduction of *Galba truncatula* (26) too was very appreciable. The species mentioned so far occur in every sample of subperiods IV/5 and IV/6. *Pisidium personatum* (25) and *Pisidium obtusale* (23) are missing from the lowest sample, *Stagnicola palustris* (20) from the uppermost, and *Segmentina nitida* (8) is again absent from the lowest sample. The general decrease of the numbers of indivi-

duals is large for all these species, but the most striking decrease is observed in the case of sligthly heat-requiring *Pisidium obtusale,* because this fell from second to ninth place. *Valvata cristata* (6), *Gyraulus albus* (3) and *Gyraulus laevis* did not occur in subperiod IV/5, but even here they appear only sporadically. In contrast, *Bithynia leachi* does not occur here, but it was found in subperiod IV/5 as 2 individuals in only one sample. Overall, there was permanent standing water on the area at the time of this subperiod too. The essential difference compared with subperiod IV/5 is not in the species, but in their much lower numbers of individuals, and this may be attributed not to the lower amount of water, but to its lower temperature.

Amphibiotic fauna: 2 species, 974 individuals. *Succinea oblonga* (946) forms a series here too. With the exception of the penultimate sample, where the number of individuals is strikingly high, its numbers of individuals are much lower than in subperiod IV/5. There was sufficient waterside everywhere for the welfare of the species, and the variations in the numbers of individuals were caused by changes in temperature which were favourable or not, depending on the species. The formation of the waterside vegetation does not mean much here; the species at present occurs in large numbers on the sparsely vegetated banks of waters on the Great Hungarian Plain. *Carychium minimum* (28) also occurred in this sample which is rich in individuals. It is a eurythermal species.

Hygrophil ubiquists: 8 species, 649 individuals. *Vallonia costata* did not appear in subperiod IV/5, but all the other 7 species are common to the two subperiods. *Vallonia pulchella* (465) dominates, but its number of individuals is high only in the penultimate sample. It forms a series as a continuation from its first appearance in the lowest sample of subperiod IV/5. *Euconulus trochiformis* (51) forms a series here too, as in subperiod IV/5. 47 of its individuals were in the penultimate sample. *Pupilla muscorum* appeared in only the two uppermost IV/5. The majority of the slightly heat-requiring *Vertigo pygmaea* (48) are also found in the penultimate sample. Its series extends with 1 individual into the lowest sample of subperiod IV/5. The relatively heat-requiring *Vallonia enniensis* (47) was found in only the two middle samples, and 46 of these were in the penultimate sample. Pupilla muscorum appeared in only the two uppermost samples, *Deroceras agreste* (8) in only the two middle samples, and *Vallonia costata* (9), which prefers the warmth, and *Cochlicopa lubrica* (5), which requires moisture, were found only in the uppermost and the penultimate samples. The category is somewhat richer here than it was in subperiod IV/5, the reason for this probably being that the water inundated the area more rarely. It follows from the fauna that the environment was humid and bushy.

Inhabitants of the groves: 2 species, 17 individuals. They are restricted to only the two uppermost samples. *Arianta arbustorum* (14) indicates a bushy environment, and *Pupilla sterri* (3) a climate colder than that of today.

The thermophilics are represented by only one individual of *Imparietula tridens,* which occurred in the uppermost sample. The cool humid environment did not favour the thermophilics.

Overall, permanent standing water existed on the area; this was supplied by precipitation from a climate of an oceanic nature, similarly to that of subperiod IV/5, but much colder. The sides of the water were covered by bushy vegetation, but there was no closed woodland there.

Subperiod IV/7, 53,9—54,7 m

This is 80 cm thick, and consists of two 30 cm and one 20 cm samples. The sparsity of its fauna is well defined both upwards and downwards. Its material is running sand. The number of species is 13, and of individuals is 82.

Aquatic fauna: 6 species, 21 individuals. None of the species extends to all three samples. *Anisus planorbis* (6) and *Pisidium cinereum* (5) are found in only the uppermost and lowermost samples, *Anisus leucostoma* (3), *Gyraulus crista* (3) and *Valvata pulchella* (2) only in the uppermost sample, and *Anisus spirorbis* only in the middle sample. The fauna consists of oligothermal *(Valvata pulchella, Anisus leucostoma)* and hardy ubiquist species. Since water was present at the time of the formation of every sample, the cold too may have played a part in the sparsity of the fauna, and the water may have arisen from the thawing of the frozen soil.

Amphibiotic fauna: 2 species, 36 individuals. *Succinea oblonga* (35) forms a series in which the low numbers of individuals are striking in comparison with those of the neighbouring subperiods both upwards and downwards. Since the water necessary for the welfare of the species was present, the low numbers of individuals were caused by the unfavourable cold. In the middle sample one *Carychium minimum* individual also occurred.

Hygrophil ubiquists: 5 species, 25 individuals. Only *Vallonia pulchella* (20) occurred in all three samples. This is a species which requires moisture, but which tolerates cold well. Its relatively low numbers of individuals here may point to cold. *Trichia hispida* (2) was also found in the lowest sample. This is missing from the neighbouring subperiods upwards and downwards. As a charasteristic loess-snail it may indicate cold here. *Vertigo pygmaea* (1) was found only in the uppermost sample, *Euconulus trochiformis* (1) only in the middle sample, and *Vallonia enniensis* (1) only in the lowest sample. The sparsity of the fauna must be attributed to the dry cold and the open vegetation.

There are no grove-dwelling or thermophilic fauna. The former confirms the dryness, the latter the cold.

Overall, the following may be reconstructed on the basis of the fauna: a dry, cold continental climate, open vegetation, standing water, which locally may have been seasonal and which may have arisen from the thawing of the soil frozen in winter.

Subperiod IV/8, 54,7—56,5 m

This is 180 cm thick, and consists of four 20 cm, two 30 cm and one 40 cm boring samples. Its material is running sand, which in the two lowest samples (56,1—56,5 m) is mixed with mud and a little humus. Its aquatic fauna too can be well distinguished, for it becomes strikingly richer from the uppermost sample on, whereas it completely vanishes in the lowest sample; this indicates the beginning of the lower arid period (V). 26 species and 1314 individuals were found in the subperiod.

Aquatic fauna: 12 species, 512 individuals. The hardy ubiquist *Pisidium cinereum* (125) forms a complete series. In terms of numbers, the oligothermal *Anisus leucostoma* (109) next follows, but in only three samples, and the bulk of it (90 individuals) in only one of them. *Anisus planorbis* (99)

Astronomical chronology	antiglacial	subtropical	glacial	subarctic	glacial	subtropical	antiglacial	subtropical	glacial	subarctic	glacial	subtropical
Mollusca subperiods	Mindel—Riss interglacial											
Stratigraphical proxle	IV. 1		IV. 2		IV. 3		IV. 4		IV. 5	IV. 6	IV. 7	IV. 8
Stratigraphical profile	Rumming sand		Fine sand with loess and mud and with a little humus		Mud with humus and running sand		Running sand with mud	Running sand		Running sand with mud	Running sand	Running sand with much mud	Running sand with mud little humus

Species \ Depth m	44·2—44·6	44·6—45	45—45·4	45·4—45·8	45·8—46·3	46·3—46·6	46·6—46·9	46·9—47·2	47·2—47·6	47·6—48	48—48·3	48·3—48·6	48·6—48·9	48·9—49	49—49·2	49·2—49·4	49·4—49·6	49·6—50	50—50·3	50·3—50·7	50·7—51·2	51·2—51·6	51·6—51·9	51·9—52·2	52·2—52·4	52·4—52·7	52·7—53	53—53·3	53·3—53·6	53·6—53·9	53·9—54·2	54·2—54·5	54·5—54·7	54·7—55	55—55·2	55·2—55·5	55·5—55·9	55·9—56·1	56·1—56·3	56·3—56·5
Valvata cristata O. F. MÜLL.																				1,								4,	2,								1,		
Valvata pulchella Studer			1,																					197,	356,	513,	4,	11,	9,	4,	2,			7,	2,		3,	3,	4,	
Bithynia leachi Shepp.		56,	79,	14,	3,	3,	1,	67,	2,	6,	3,	3,	1,				1,			1,				2,															
Stagnicola palustris O. F. MÜLL.	1,	13,	9,							5,	1,										4,	1,	4,	98,	40,	73,		5,	12,	3,				6,	2,		3,	2,	1,
Galba truncatula O. F. MÜLL.			2,					3,																48,	110,	42,	2,	2,	21,	1,				3,	2,		11,	4,	
Physa fontinalis L.																							1,														1,		
Aplexa hypnorum L.																								9,	5,	2,			1,										
Planorbis corneus L. inv.		3,	1,																																				
Anisus planorbis L.	2,		1,							1,							5,	2,	7,	6,	2,	16,		349,	445,	775,	65,	34,	67,	12,	3,		1,	47,	25,	3,	8,	8,	7,	1,
Anisus carinatus O. F. MÜLL.																								5,	2,	3,			1,										
Anisus leucustoma MILLET																								1,	9,	18,	3,	1,	19,	12,	3,				8,		90,	11,	
Anisus spirorbis L.																						13,		54,	154,	1178,	92,	47,	172,	8,		2,		19,	3,	1,	2,	9,	5,	1,
Gyraulus albus O. F. MÜLL.																											1,	1,											
Gyraulus laevis Alder	6,	3,								2,																		1,											
Gyraulus crista L.	1,	5,	3,					1,		8,	1,	1,												82,	323,	787,	24,	9,	32,	4,	3,			26,	7,		3,	2,	3,	
Segmentina nitida O. F. MÜLL.																								2,	19,	49,	5,	1,	2,										
Pisidium cinereum Alder	4,	195,	36,	3,				3,		109,	18,	5,	2,						1,	1,	3,		46,	990,	1130,	1835,	152,	95,	139,	20,	4,		1,	21,	24,	2,	11,	30,	35,	2,
Pisidium personatum Malm.																								84,	159,	103,	5,	2,	18,									1,	
Pisidium obtusale C. PFEIFF.	2,	3,									1,													243,	588,	899,	6,	2,	15,					39,	1,		2,		
Aquatic species altogether	16,	278,	132,	17,	3,	3,	1,	74,	2,	131,	24,	9,	3,	—,	—,	—,	1,	5,	3,	10,	13,	3,	80,	2146,	3340,	6277,	359,	216,	510,	64,	17,	2,	2,	168,	74,	6,	29,	158,	72,	5,
Carychium minimum O. F. MÜLL.																												28,			1,						8,		
Succinea putris L.	1,	2,	1,			1,																																	
Succinea oblonga Drap.	74,	54,	19,	9,	1,	14,	8,	19,	3,	2,	2,	9,	42,	19,	5,	3,	5,	18,	7,	31,	19,	4,	42,	81,	65,	110,	38,	43,	833,	32,	15,	7,	13,	35,	23,		18,	161,	64,	9,
Succinea pfefferi Rm.																										2,													
Amphibiotic species altogether	75,	56,	20,	9,	1,	15,	8,	19,	3,	2,	2,	9,	42,	19,	5,	3,	5,	18,	7,	31,	19,	4,	42,	81,	65,	112,	38,	43,	861,	32,	15,	8,	13,	35,	23,	—,	18,	169,	64,	9,
Cochlicopa lubrica O. F. MÜLL.	19,	21,	1,	1,					1,	7,	32,	27,	15,	1,	1,			5,	2,	15,	12,	9,	8,	17,	1,		2,		3,					1,	1,					
Vertigo pygmola Drap.	2,	2,											3,	1,	1,			4,	2,	4,	2,	2,				1,	2,	2,	40,	4,	1,			3,			1,	2,		
Pupilla muscorum L.	9,	6,						2,	2,	54,	94,	128,	30,	15,	2,		3,	7,	2,	16,	8,	14,	3,	1,	1,	4,	5,	11,										4,	1,
Vallonia pulchella O. F. MÜLL.	6,	13,								4,	7,	13,										1,				5,	1,	6,	437,	21,	14,	2,	4,	11,	2,		311,	17,	1,
Vallonia enniensis Gredler																								1,	1,	1,		1,	46,				1,	9,	2,		2,	12,		
Vallonia costata O. F. MÜLL.		1,								10,	12,	20,	13,	3,		2,		3,	2,	9,	2,		1,				3,		6,										
Punctum pygmaeum Drap.	4,	2,											1,																										
Euconulus trochiformis Mont.	6,	2,								13,	5,	3,									1,	1,	1,	1,	3,	3,	1,	1,	47,	2,		1,		1,	2,		18,	6,	
Deroceras agreste L.	3,	15,	11,	8,	2,	5,	1,	15,		2,	9,	5,	8,	4,	3,			4,	1,	5,	1,			2,	1,			4,	4,					1,		2,	1,	2,		
Trichia hispida L.	65,	79,	9,			4,		29,	10,	50,	144,	84,	24,	1,		1,	5,	5,	6,	15,	4,	4,	2,										2,							
Hygrophil ubiquist species altogether	114,	141,	29,	9,	2,	9,	1,	46,	13,	140,	303,	280,	94,	25,	7,	3,	8,	28,	15,	64,	30,	31,	15,	22,	7,	14,	14,	25,	583,	27,	15,	3,	7,	26,	7,		4,	343,	31,	2,
Columella edentula Drap.		1,																																					
Pupilla sterri v. Voith											7,															1,	1,	2,									1,		
Clausilia dubia Drap.		3,																																					
Perpolita hammonis Strōm.	7,	9,		1,						5,	3,	9,	5,	1,						2,	2,			2,	1,	3,								3,						
Arianta arbustorum L.	7,	6,																									3,	11,											
Inhabitant of the groves altogether	14,	19,	—,	1,	—,	—,	—,	—,	—,	5,	3,	16,	5,	1,	—,	—,	—,	—,	—,	—,	2,	2,	—,	2,	1,	4,	4,	13,	—,	—,	—,	—,	—,	3,	—,	—,	—,	1,	—,	—,
Imparietula tridens O. F. MÜLL.	1,											1,	17,	20,	4,	4,	6,	10,	7,	18,	6,	2,	3,				1,												2,
Helicella hungarica Soós et WAGNER													1,	1,			1,	1,																1,	2,	2,	4,	6,	36,	14,
Thermophilic species altogether	1,	—,	—,	—,	—,	—,	—,	—,	—,			1,	18,	21,	4,	4,	7,	11,	7,	18,	6,	2,	3,	—,	—,	—,	1,	—,	—,	—,	—,	—,	—,	1,	2,	2,	4,	6,	36,	16,
Mollusca exemplars altogether	220,	494,	173,	36,	6,	27,	10,	139,	18,	278,	332,	315,	162,	66,	19,	10,	21,	62,	32,	125,	70,	40,	140,	2269,	3413,	6407,	416,	297,	1954,	123,	47,	13,	22,	233,	106,	8,	55,	677,	203,	32,

Astronomical chronology	antiglacial	subtropical	glacial	subarctic	glacial	subtropical	antiglacial	subtropical	glacial	subarctic	glacial	subtropical
Mollusca subperiods	Mindel—Riss interglacial											
Stratigraphical proxle	IV. 1		IV. 2		IV. 3		IV. 4		IV. 5	IV. 6	IV. 7	IV. 8
Stratigraphical profile	Rumming sand	Fine sand with loess and mud and with a little humus			Mud with humus and running sand		Running sand with mud	Running sand		Running sand with mud	Running sand	Running sand with much mud	Running sand with mud little humus

Species \ Depth m	44·2—44·6	44·6—45	45—45·4	45·4—45·8	45·8—46·3	46·3—46·6	46·6—46·9	46·9—47·2	47·2—47·6	47·6—48	48—48·3	48·3—48·6	48·6—48·9	48·9—49	49—49·2	49·2—49·4	49·4—49·6	49·6—50	50—50·3	50·3—50·7	50·7—51·2	51·2—51·6	51·6—51·9	51·9—52·2	52·2—52·4	52·4—52·7	52·7—53	53—53·3	53·3—53·6	53·6—53·9	53·9—54·2	54·2—54·5	54·5—54·7	54·7—55	55—55·2	55·2—55·5	55·5—55·9	55·9—56·1	56·1—56·3	56·3—56·5

forms a complete series, but the bulk of it (72) is in the two uppermost samples, where it may indicate an abundance of water. The slightly thermophilic *Pisidium obtusale* (42) occurs in only three samples, the overwhelming majority of it (39) in the uppermost sample. *Gyraulus crista* (41) forms a defective series, and does not occur in only two samples. *Anisus spirorbis* (40) was found in every sample. Of the 7 samples of the subperiod, *Galba trunculata* (20) was present in four, *Valvata pulchella* (19) in five, and *Stagnicola palustris* (14) also in five. *Valvata cristata* (1), *Physa fontinalis* (1) and *Pisidium personatum* (1) were all minimal.

Overall, standing water existed on the area; this was supplied by the precipitation from an oceanic-type climate. Meanwhile the conditions changed. There is a very clear boundary between the lower arid period and the lowest sample in this subperiod; the moistening increases rapidly upwards through three samples. It decreases considerably in the next sample, and one sample higher it is at a minimum (only 3 species and 6 individuals). It next rapidly increases again, and culminates in the highest sample.

Amphibiotic fauna: 2 species, 318 individuals. *Succinea oblonga* (310) is much more frequent than in subperiod IV/7, which may be attributed to the greater amount of water and the milder climate. Its numbers of individuals fluctuate together with the aquatic fauna. It is missing from the sample where the aquatic fauna is at a minimum. *Carychium minimum* (8) was found in only that sample where *Succinea oblonga* was at a maximum.

Hygrophil ubiquists: 7 species, 413 individuals. *Vallonia pulchella* (342) dominates, but it is missing from the third and fourth samples, and culminates together with *Succinea oblonga* in the fifth sample. *Euconulus trochiformis* (27) is present in only four samples, and culminates in the same place. *Vallonia enniensis* (25) was found in four samples too, indicating some degree of heat. *Vertigo pygmaea* (6) appears in only three samples, in the milder parts of the subperiod. *Deroceras agreste* (6) is distributed fairly uniformly between four samples. *Pupilla muscorum* (5) occurs in only the two lowest samples, where it may point to a certain warmth. *Cochlicopa lubrica* (2) appears in only the two uppermost samples. The values of the *Mollusca* exemplars together show the same fluctuation as was observed in the values of the aquatic species together.

Inhabitants of the groves: only 2 species and 4 individuals. These were *Perpolita hammonis* (3) in the uppermost sample, and *Pupilla sterri* (1) in the fifth sample.

Thermophilics: 2 species, 67 individulas. *Helicella hungarica* (65) forms a complete series, though until now it had scarcely appeared in the whole of period IV (in subperiods IV/3 and IV/4 together it had only 4 individuals). It indicates a sunny and hot place, perhaps covered by bushes. On the basis of the numbers of individuals the temperature may have been lower than today's, with the exception of the two lowest samples, where the bulk of the individuals (50) were found. *Imparietula tridens* (2) appeared in only the lowermost sample.

Overall, there was standing water at the time of the subperiod, and this was supplied by a climate of an oceanic type. The temperature at the time of formation of the two lowest samples was higher than for the other samples. Locally the vegetation did not form a closed wood.

The stratigraphical chronology

The lower humid period is part of a deposit-series which is variable in structure but which does not contain a loess layer; thus, there was no loess-forming, ice period during its development. The nearest loess layer is found only well below the boundary of period IV, at a depth of 71 m. As a result of the situation and extent of this deposit-series, it must be considered as a deposit of the Mindel—Riss interglacial. The variation of the deposits within this indicates the variation of the factors forming the deposit. The geological section of MIHÁLTZ shows a ninefold change in the deposit formation during period IV. These are discussed below, starting from the top:

44,2—44,6 m. Running sand. This indicates that westerly winds prevailed, because the running sand could have been transported from the bed of the Danube to the more easterly Felsőszentiván by festerly winds. The absence of humus points to the lack of sufficient vegetation for the formation of humus, and the lack of vegetation to the aridity. This deposit is the uppermost sample of the *Mollusca* subperiod IV/1, in which the effect of a dry climate is likewise confirmed by the sudden sparsity of the aquatic fauna. (The running sand continues upwards to a depth of 40 m, but this higher part belongs to period III, the middle arid period.)

44,6—47,6 m. Fine sand with loess and mud, and with a little humus. The fine sand indicates the weakening of the westerly winds, because these were now able to transport only the finer alluvium, and the loess shows that there were also easterly winds. The mud points to water, and the small amount of humus to a flora suitable for humus formation. The deposit extends to 8 samples, 6 of which fall in subperiod IV/2. The fauna here demonstrate the flora, water and cold continental effect necessary for the transport of the loess. The two lowest samples of subperiod IV/1 also belong here. The milder and moister effect thus reconstructed affected the fauna favorably, but it was not sufficient to influence the quality of the deposit formation.

47,6—49,4 m. Mud with humus, and running sand. The higher mud content points to more moisture, the higher humus content to a richer vegetation, and the running sand to the occurrence of westerly winds and an open flora. 5 of the 7 samples of the deposit coincide with subperiod IV/3, and the two lowest samples form the upper part of subperiod IV/4. On the basis of the fauna, subperiod IV/3 was moister, milder, and richer in flora than subperiod IV/2, and thus the fauna gives grounds for the higher mud and humus. The mud (fine deposit) at the top of subperiod IV/4, showing an arid environment, may have become mixed with the running sand by the drying up of the older water, by being washed in, or by being blown in.

49,4—50 m. Running sand with mud. These are two samples from the arid, warm subperiod IV/4, in which the decreasing aquatic fauna is still present, and in which the species *Helicella hungarica,* which requires heat, occurs. The silting up may be parallel with the drying up of the water.

50—53,3 m. Running sand. On the basis of the conclusions drawn from the fauna, here belong the 5 lowest samples of subperiod IV/4 with a dry and warm climatic effect, subperiod IV/5 with a strikingly rich aquatic fauna and a mild and moist climate, and the upper part of subperiod IV/6 with a moist climate cooler than the above. Accordingly the westerly winds transported the

sand here in three different types of climate. This finding does not contradict any of the scientific conceptions. The sand was in part deposited in water, and humus from the open vegetation reconstructed on the sides of the water did not remain in it.

53,3—53,9 m. Running sand with mud. This is the lower half of subperiod IV/6. The deposit can also be easily distinguished on the basis of the fauna, because the combined values of the aquatic, amphibiotic and ubiquist categories culminate in a striking way in the uppermost sample, while the lowest sample is bordered by a different climatic type. If the complete picture of the fauna and the conditions reconstructed within this are taken into consideration, however, a separate treatment is not considered justified. Nevertheless, it must be noted that mud is mixed into the running sand on the beginning of the development of water and at the end of the drying up process. It is perhaps not accidental that the thicknesses of the mixtures both above and below the sand are each 60 cm.

53,9—54,7 m. Running sand. This coincides with subperiod IV/7. The dry, cold climate and sparse vegetation reconstructed from the mediocre fauna completely justify that neither mud nor humus became mixed in with the sand.

54,7—56,1 m. Running sand with much mud. These are the upper 5 samples of subperiod IV/8. The presence of water and the cool, moist climate deduced from the fauna explain both the running sand and the mud.

56,1—56,5 m. Running sand with a little humus and mud. It differs from the previous deposit by the presence of a little humus. It extends to the two lowest samples of subperiod IV/8. According to the fauna, the climate here was moist, similarly to the other parts of the subperiod, but it was warmer than these. The humus is the residue from the richer vegetation resulting from the greater heat.

Astronomical chronology

The Mindel—Riss interglacial is very heterogeneous, and presents many different climatic changes on the MILANKOVICH—BACSÁK cliamte-curve. Its sole generally characteristic feature is that during this time there was no successful glaciation. With this in mind, one is automatically reminded of the geological section, where there is one common feature in the great variety of the deposits: they do not contain a loess layer, and there was thus no loess-forming period, that is glaciation, during their development. The many variations of the environmental conditions are also reflected by the *Mollusca* fauna. In the following an attempt is made to follow the changes of the astronomical curve by the changes of the fauna, as was also done in the preceding papers of this series. The previous paper ends with subperiod III/13, which extends from 40 m to 44,2 m, and consists of running sand; this was identified with the 5700 years subarctic period preceding the Riss I glacial. In the lower humid period below this, the following ages are found on the climate-curve in the direction of earlier times.

A n t i g l a c i a l a g e. Duration: 6000 years. It can be identified with the uppermost sample of subperiod IV/1, which is the 40 cm continuation of the running sand already mentioned. The great decrease of the aquatic fauna here corresponds to the hot, arid type of climate.

Subtropical age. Duration: 12000 years. A hot, oceanic type of climate, which can be identified with the two lowermost samples of subperiod IV/1, because the richness of the aquatic fauna in these is striking.

Glacial age. Duration: 2500 years. A cold, oceanic type of climate. This can be identified with the uppermost sample of subperiod IV/2, where the aquatic fauna is much richer than lower down, but much poorer than higher up.

Subarctic age. Duration: 12500 years. A cold continental type of climate, which corresponds very well to the tundra-like conditions reconstructed from the fauna of the other five samples of subperiod IV/2.

Glacial age. Duration: 8500 years. This can be identified with the three uppermost samples of subperiod IV/3. The cool oceanic climatic effect, more favourable than the subarctic one, is indicated primarily by the striking richness of the ubiquist fauna.

Subtropical age. Duration: 2800 years. This is the same as the two lowest samples of subperiod IV/3, where the moisture at a favourable temperature produced by this type of climate is indicated by the high individual numbers of *Succinea oblonga*, and the increased heat by the high numbers of individuals of the thermophilic fauna compared with the other samples of the subperiod.

Antiglacial age. Duration: 10400 years. This may be indentified with subperiod IV/4. The aridity corresponding to the type of climate here is indicated by the gradual decrease and finally the disappearance of the aquatic fauna, and the warmth by a complete series of the thermophilic *Imparietula tridens*.

Subtropical age. Duration: 6100 years. This corresponds to subperiod IV/5, the strikingly rich aquatic fauna of which is in perfect agreement with the warm oceanic type of climate.

Glacial age. Duration: 4000 years. The very rich, but much poorer than previously, aquatic fauna of subperiod IV/6 corresponds to this cool oceanic type of climate (more unfavourable in its temperature effect).

Subarctic age. Duration: 10300 years. A dry, cold climatic type. The sparse fauna of subperiod IV/7 indicates conditions in complete accordance with this.

Glacial age. Duration: 7500 years. The five uppermost samples of subperiod IV/8, with aquatic fauna and *Helicella hungarica* in every sample, may be identified with the deposit in this cool, oceanic climate, which was much more favourable than previously.

Subtropical age. Duration: 2900 years. A mild, oceanic type of climate. This is identified with the two lowest samples of subperiod IV/8, where the favourable effect of the moisture is confirmed by the occurrence and multiplication of the aquatic fauna, and the greater warmth in the upper part of the subperiod by the strikingly higher numbers of individuals among the thermophilic fauna.

(To be continued)